US Phase-II Pixels Scrubbing Meeting

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LBNL

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NATIONAL ACCELERATOR LABORATORY

Phase-II Pixels

- Scoping Document (SD): 4 Layers, eta=4.
- All Budget numbers based on SD.
- Un-official decision to add a 5th Pixel Layer.
- TWO layouts being evaluated:
    - Unity (US-UK): I-Beams (LBNL) with long inner barrel for high eta, + rings.
    - Inclined (two versions: Alpine and SLIM).
    - Simulations about to be launched.
    - Decision: Spring 2016.
- Beyond layout, lots of unknowns: services (on/off stave), optical links, etc…

SD: ITk CORE Estimate

Table 13. CORE cost estimates for the ITk project for the three scoping scenarios.

WBS	Item	Reference Total Cost [kCHF]	Middle Differential Cost [kCHF]	Low Differential Cost [kCHF]
2	**ITk system**	**120,422**	**-7,215**	**-23,598**
2.1	**PIXEL detector**	**32,187**	**-915**	**-4,798**
2.1.1	Sensors	7,008	-205	-1,148
2.1.2	FE Electronics	11,301	-314	-1,699
2.1.3	Further Electronics	4,298	-92	-564
2.1.4	Off-Detector Electronics	5,387	-156	-977
2.1.5	Mechanics	4,192	-148	-410
2.2	**STRIP detector**	**72,100**	**-6,300**	**-18,800**
2.2.1	Sensors	29,100	-2,300	-8,500
2.2.2	FE Electronics	3,600	-200	-800
2.2.3	Further Electronics	15,400	-1,500	-4,700
2.2.4	Off-Detector Electronics	9,600	-1,200	-2,100
2.2.5	Local Supports	6,600	-600	-1,300
2.2.6	Global Supports	7,800	-500	-1,400
2.3	**COMMON items**	**16,135**	**-**	**-**
2.3.1	Mechanics	12,760	-	-
2.3.2	Electronics	3,000	-	-
2.3.3	TTC Infrastructure	375	-	-

SD: ITk Schedule

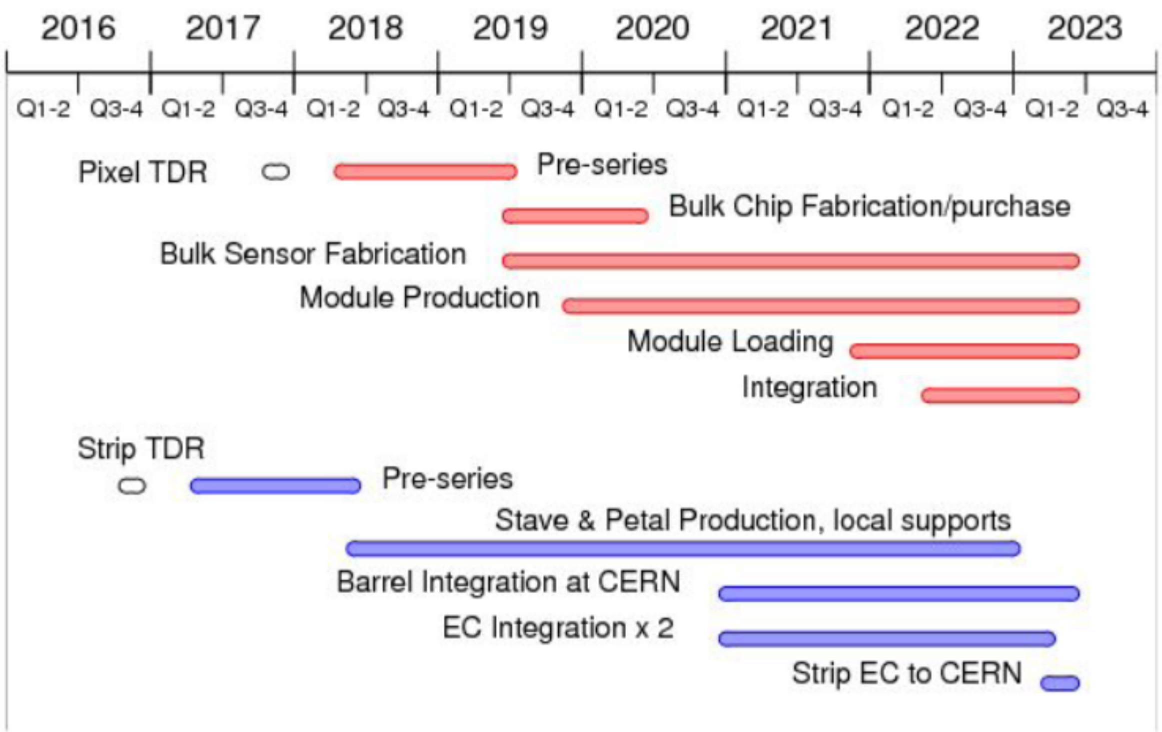
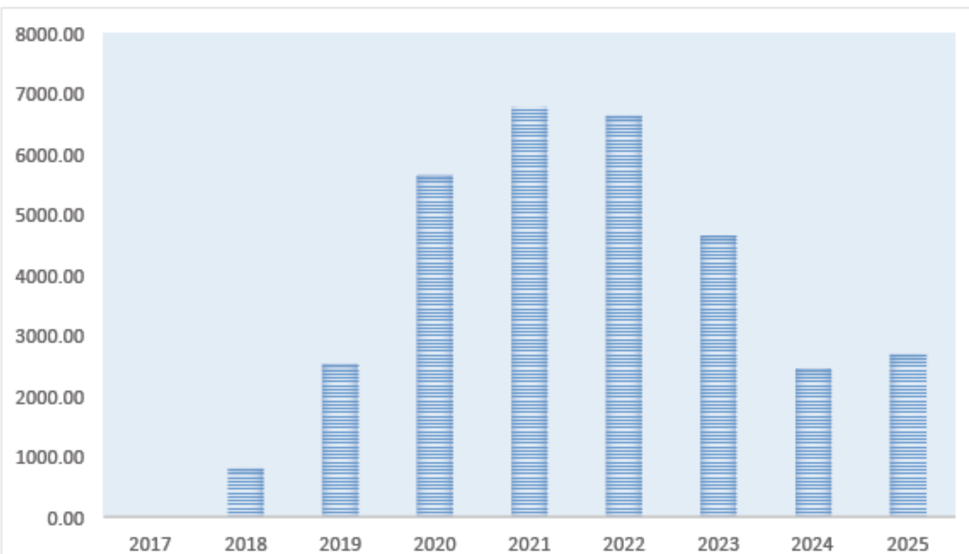


Figure 17. The schedules for the pixel and strip systems from the TDR phase into pre-production and then series production.

SD: ITk CORE Estimate – Profile.

Item	Cost	2017	2018	2019	2020	2021	2022	2023	2024	2025	Tot
Sensors	7008.62			10	30	30	20	10			100
FE-chip	2705.41		30	20	20	20	10				100
Bump-bonding	8595.72			15	25	25	25	10			100
Local support	4192.11				10	20	30	30	10		100
On-detector electornics	4298.66				10	20	30	30	10		100
LV/HV	1741.50					5	5	10	30	50	100
Cables/Fibers	3645.54					5	5	10	30	50	100
Total	32187.55	0.00	811.62	2531.30	5641.67	6760.10	6637.78	4646.37	2465.19	2693.52	32187.55



US Pixel Budget

- Inputs/wishes from all Institutes (x12) received in September: Inputs to JOG.
- Labor/MS/Travel: $31.118M Versus $21.181M (guidance).

- However, some "easy" savings:
    - Need 2 Module Assembly sites (versus 4 in wish-list).
    - Need 1 Stave Loading site (versus 2).
    - Need 1 Powering option (versus 2).
    - Need 1 Optical Links option (versus 2).
    - Scope of Test Setups reduced.

- For a deliverable with several options:
    - Picked most conservative (expensive) option.
    - NOT making any technical decisions.

US Pixel: base budget

- Guidance from US-ATLAS Management, from JOG Meeting (end of September): Pixels budget: $27.124M:
  - CORE: $5.943M.
  - Labor/MS/Travel: $21.181M.

US ATLAS PHASE-II UPGRADE **BUDGET PROFILE**

DOE Scope WBS		FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	Total
6.1	Pixels	52	1,620	4,388	5,114	6,385	5,968	3,168	377	-	27,071
6.2	Strips	1,284	5,370	9,872	10,195	8,583	6,567	3,929	-	-	45,799
6.3	ITK Common	-	261	483	1,257	1,274	1,274	800	316	169	5,833
6.4	LAr	-	76	151	151	-	-	-	-	-	378
6.7	TDAQ	-	-	386	386	386	1,205	1,135	1,135	567	5,201
	Common	-	-	-	630	630	630	630	630	630	3,779
	Proj. Management	-	1,055	1,055	1,055	1,055	1,055	1,055	1,055	1,055	8,438
	Contingency	668	4,191	8,167	9,394	9,156	8,349	5,358	1,756	1,211	48,249
	Total	**2,004**	**12,572**	**24,502**	**28,182**	**27,467**	**25,048**	**16,073**	**5,268**	**3,632**	**144,747**
	DOE Guidance	1,250	14,000	31,500	42,300	26,100	20,100	8,000	1,750	-	145,000

- On October 21st: US Pixel meeting – very useful to define/redefine US Scope and identify potential/existing issues.
- Since then, very intense interaction with all Institutes to refine scope and cost estimates.

- No FY17 Construction funds (for Pixels) – Wish-list has $3.1M:
  - Rely on R&D funds (not sufficient).
  - Move some costs to later years.
  - Cut some costs.

US Pixel: Refining the scope

- Powering: Serial Powering at OkS and Pulsed Powering at OU. Similar cost (non-CORE). Keep Serial Powering (OkS) in reference budget.

- Stave flex: UNM main driver, OkS wanted to be involved at Design Level, but no really need, so activity dropped at OkS (concentrating on Serial Powering).

- Two Module Assembly sites: SD has 8K modules, so two Module Sites in the US is sufficient: ANL, LBNL, SLAC and UCSC.
  **** NEED to update (reduce) labor cost/profile ****

- Module Testing: UNM and OU (HALT/HASS) participating (modest cost).

- Developed a common cost for Module Assembly/Testing/Shipping:

- One Stave (local support) site in the US: ANL and SLAC (SLAC drops Module Assembly if Stave loading).
  - Loading of Inner Layers (16 I-beams)?
  - 1/3 of barrel staves (50 I-Beams in total)?

  *** assuming final layout has I-Beams everywhere.

US Pixel: Refining the scope

- Optical Links: two options being pursued in the US:
  - 12-channel array at OSU (Current Pixel + IBL), standalone approach.
  - 4/12-channel array at SMU, in collaboration with CERN VL+ team.
  - No technical decision. For budget, used OSU (most conservative).
  - If OSU: will need to fabricate ALL boards (CORE – included in reference budget). If other option, contribute partially to fabrication cost.

- Wisconsin: will follow current model, sending students/postdocs at LBNL to work on Module Assembly and Front-end Chip:

- **In new reference scope/budget, ALL US Pixel Institutes involved in Construction.**

US Pixels WBS

6.1.1 Pixels_ANL (Jimmy Proudfoot)
6.1.2 Pixels_LBNL (Maurice Garcia-Sciveres)
6.1.3 Pixels_SLAC (Su Dong)
6.1.4 Pixels_OSU (KK Gan)
6.1.5 Pixels_SMU (Jingbo Ye)
6.1.6 Pixels_UCSC (Mike Hance)
6.1.7 Pixels_OkS (Flera Rizatdinova)
6.1.8 Pixels_UNM (Sally Seidel)
6.1.9 Pixels_Washington (Shih-Chieh Hsu)
6.1.10 Pixels_Wisconsin (Sau Lan)
6.1.11 Pixels_OkU (Philipp Gutierrez)
6.1.12 Pixels_SB (Dmitri Tsybychev)

L4 Deliverables:

1. Integration.
2. Global Mechanics.
3. Services.
4. Local Supports.
5. Modules.
6. Off-Detector Elec.
7. Support (Test setups and Irradiations/Testbeam).

US Reference Budget/Scope Summary

Deliverable	Item	Institutes	Non-CORE Cost	CORE Cost	Total Cost
Integration	Integration	LBNL	570.480	0.000	570.480
Mechanics	IST	WA, LBNL	836.954	250.000	1086.954
Services	Twinax	SLAC	987.926	388.000	1375.926
	Optical links	OSU (SMU)	1864.986	642.900	2507.886
Local Supports	I-Beam	LBNL, ANL, SLAC	4116.647	500.000	4616.647
	Twisted pairs	UCSC	641.037	15.000	656.037
	Stave-flex	UNM	549.403	840.000	1389.403
	End Of Stave	SLAC	527.736	15.000	542.736
	Stave Loading	SLAC	1931.700	0.000	1931.700
Modules	Module Assembly/Testing	ANL, LBNL-Wisconsin (UCSC, SLAC)	4230.242	1869.000	6099.242
	Module Testing	UNM, OkU	398.449	0.000	398.449
	FE Chip	LBNL-Wisconsin, WA	1248.079	588.000	1836.079
	Bump bonding	SLAC (ANL, UCSC)	173.886	0.000	173.886
	3D Sensor Testing	UNM	72.056	0.000	72.056
Off-Detector Elec.	Powering-Serial	OkS (OkU)	732.344	567.900	1300.244
Support	Support	ANL, SLAC, WA, SB, UNM	1872.467	0.000	1872.467
TOTAL			**20754.394**	**5675.800**	**26430.194**
Guidance			**21181.000**	**5943.000**	**27124.000**
Balance			**426.606**	**267.200**	**693.806**

US Deliverables

Item	Institutes	CORE Cost (k$)	Comment
IST	LBNL, Washington	250.0	
Twinax	SLAC	388.0	100% of Twinax cables – Assume 5m cables.
Optical Links	OSU (SMU)	642.9	100% of Opto Links.
I-Beams	LBNL, ANL, SLAC	500.0	100% of I-Beams Mechanics (cooling pipe).
Twisted Pairs	UCSC	15.0	100% of TP (on-stave data transmission, inner layers)
Stave Flex	UNM	840.0	100% of Flexes (on-stave data transmission, outer layers)
End of Stave	SLAC	15.0	100% of Barrel EoS cards (x100).
Module Assembly	ANL, LBNL (UCSC, SLAC)	1869.0	20% of Bump-Bonding cost.
Front-End Chip	LBNL, WA	588.0	20% of FE Chip cost.
Powering	OkS/Serial (OkU/Pulse)	567.9	30% of HV/LV Power Supplies.
TOTAL		**5675.8**	
Guidance		**5943.0**	

US Pixel Scope at Institutes

Module Assembly/Testing

- SD has 8K modules, so with spares/preprod ~ 10K, about 2K in the US.
- Two Assembly sites: ANL, LBNL, SLAC and UCSC.

- Labor cost, used two most conservatives estimates.
- *** Need to standardize labor needs between all groups.
- CORE cost: 20% for ATLAS (FE + BB): $2457K.

- Other costs: same for all groups: $330K/site:
  - NO Travel.
  - MS: glue, wirebonds, etc…: $30K.
  - Testing Equipment: $35K.
  - Shipping: $15K ($10-15 per module).
  - Wire bonder: $250K.

6.1.1 ANL

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.1.1	Integration	Integration		N	n/a
6.1.1.4	Local Support	Barrel Mechanics	Routing of the services on the I-beams. Welding of the cooling tubes.	Y	1.4
		Stave Loading	Load modules on local supports	N (SLAC)	1.5
6.1.1.5	Modules	Bump Bonding	Interface with RTI	N	n/a
		Module Assembly	Assemble/test Modules	Y	2.1
6.1.1.7	Support	Test Setups	Develop hard/software for system tests.	Y	0.6

6.1.2 LBNL

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.2.1	Integration	Integration	Integration/Project Management	Y	0.6
6.1.2.2	Mechanics	IST	CORE cost at WA	Y	0.09
6.1.2.4	Local Support	I-Beams	Fabricate I-Beams for all Pixel. 50 I-beams (includes cooling pipe). Install (?) electrical services.	Y	2.3
6.1.2.5	Modules	Front-end chip	Develop FE chip – Wafer testing.	Y	1.1
		Module Assembly	Assemble/test Modules	Y	2.1

6.1.3 SLAC

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.3.1	Integration	Integration		N	n/a
6.1.3.3	Services	Twinax	Develop twinax cables	Y	1.0
6.1.3.4	Local Support	Barrel Mechanics	I-beams Thermal/Cooling and electrical tests.	Y	0.4
		End of Stave	Develop EoS card for Barrel Local Supports.	N	0.0.5
		Stave Loading	Load modules on Stave	Y	1.9
6.1.3.5	Modules	3D Sensors	R&D	N	0.07
		CMOS	R&D	N	0.05
		Bump Bonding	Interface with RTI	Y	0.2
		Module Assembly	* Provided Stave Loading	N	2.1
6.1.3.6	Support	Test Setups	Develop hard/software for system tests.	Y	0.4
		TestBeams	Support for TB at SLAC.	Y	0.04

6.1.4 OSU

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.4.3	Services	Opto Boards	Develop and build ALL Optical links for Pixels. Assumes 10K links.	Y	1.9

6.1.5 SMU

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.5.3	Services	Opto Links	Develop Optical Links in collaboration with CERN VL+.	N	1.1

6.1.6 UCSC

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.6.4	Local Support	Twisted Pairs	For inner layers data transmission	Y	0.6
6.1.6.5	Modules	Bump Bonding	Interface with RTI	N	n/a
		Module Assembly	Assemble/test Modules	N	1.2

Scope: assume Pixels will use Twisted Pairs for Inner Layers for on-stave services.
(outer layers: flex at UNM, see next).

6.1.7 OkS

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.7.6	Off-Detector	Serial Powering	Design of Constant Current Power Supplies (and cables) for Serial Powering – CORE=30% of HV/LV power supplies.	Y	0.7

6.1.8 UNM

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.8.4	Local Support	On-Stave Flex	For outer layers *	Y	0.5
6.1.8.5	Modules	Module Testing	Test Modules.	Y	0.09
		3D Sensors	FBK sensors Testing	Y	0.07
6.1.8.7	Support	Irradiation	Support for Irradiation	Y	0.1

Scope: assume UNM will build flexes for <u>Outer Layers</u>.
On-stave services for Inner Layers: Twisted Pairs at UCSC.
CORE cost: $820K.

6.1.9 Washington

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.9.2	Mechanics	IST	Develop IST CORE IST = $250K.	Y	0.8
6.1.9.5	Modules	FE Chip	Wafers testing for FE chip	Y	0.1
6.1.9.7	Support	Test Setups	Develop hard/software for system tests.	Y	0.3

6.1.10 Wisconsin

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.10.5	Modules	FE Chip	Participate to FE-Chip testing at LBNL.	Y	0.08
		Module Assembly	Participate to module assembly/ testing at LBNL.	Y	

Wisconsin will send Students/Postdocs at LBNL to work on FE chip testing and Module assembly. Only travel funds.

6.1.11 OU

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.11.5	Modules	Module Testing	Develop HALT/HASS (Reliability-aging tests) procedure and equipment.	Y	0.4
6.1.11.6	Off-Detector	Pulsed Powering	Develop Pulsed Powering Power Supplies for Serial Powering	N	0.6

Pulse Powering NOT in reference: use Serial Powering (OkS) – One option for Powering.

6.1.12 Stony Brook

WBS	Deliverable	Item	Scope	Reference (Y/N)	Cost($M)
6.1.12.7	Support	Test Setups	Develop hard/software for system tests.	Y	0.3

Additional Information

6.1.3 SLAC

Stave Loading:

- Assume 1/3 of Barrel Ibeams: 20 I-beams (with spares).
- Plan to develop a simple connectivity system between modules and services: NO wirebonds!
- Stave loading: 1 week – IBL was 2 weeks (most of the time spent on connectivity).
- Given small amount of staves, considering doing loading “by hands”, NO precision loading machine.
- Current budget assumes $200K for such a machine.
- Will probably optical survey: precision measurement of modules respective R position.
- M&S Costs: $350K:
  - $200K for loading machine (likely to be dropped).
  - Mechanics to hold double-sided staves, during loading and optical survey.
  - Loading equipment.
  - Testing equipment.

6.1.3 SLAC

Twinax

Phase-2 Layout-5 (ITk Week Sep/2015) 5P+4S |η|<4.0

RD53-I	count	pixel size (µm)	length (mm)	RD53-O	count	pixel size (µm)	length(mm)
Column (Z)	200	100	20		400	50	20
Row (r-phi)	672	25	16.8		672	50	33.6
Channels	134400	Area=	336		268800	Area=	672
Module Z+gap			41.5				41.6

L0 Khz	8b/10b +hdr	Link rate
1000	1.3	6.4

1 TX per 20 Modules

Layer	Radius (mm)	Half-len (mm)	nStave	FE type	nPhi/mod	nZ/mod	A+C nMod/stave	A+C nFE/stave	A+C Z-length	Area/mod	nFE/layer		nFE/Type	bits/bx/FE	Mb/s/FE	Inc OVH Mb/s/FE	Half stave rate Gb/s	nFE/Link	Rate/link Gb/s	link/half stave	RX Links/layer	TX Links/layer
1	39	1217.9	16	RD53-I	1	2	60	120	2490	1344	1920	RD53-I		7258	7258	9435.4	566.1	1	9.435	60	1920	64
2	75	1217.9	16	RD53-I	2	2	60	240	2490	2688	3840		5760	3177	3177	4130.1	495.6	2	8.260	60	1920	64
3	155	730.7	32	RD53-O	2	2	36	144	1497.6	2688	4608			3064	3064	3983.2	286.8	2	7.966	36	2304	64
4	213	730.7	44	RD53-O	2	2	36	144	1497.6	2688	6336	RD53-O		1948	1948	2532.4	182.3	2	5.065	36	3168	88
5	271	730.7	56	RD53-O	2	2	36	144	1497.6	2688	8064		19008	1464	1464	1903.2	137.0	4	7.613	18	2016	112
											All disks						Per Ring		Rate/link			
Disk	R in (mm)	R out	A+C nDisk		nPhi/mod	nR/mod	nMod/Ring	nFE/Ring			nFE/ring						rate Gb/s		Gb/s	link/ring	links/disk	
Ring 1	80	120	34	RD53-O	2	2	24	96		2688	3264			4000	4000	5200.0	499.2	2	10.400	48	1632	68
Ring 2	150	190	38	RD53-O	2	2	36	144		2688	5472			2500	2500	3250.0	468.0	2	6.500	72	2736	76
Ring 3	212.5	252.5	32	RD53-O	2	2	48	192		2688	6144	RD53-O		1800	1800	2340.0	449.3	4	9.360	48	1536	128
Ring 4	275	315	32	RD53-O	2	2	60	240		2688	7680		22560	1400	1400	1820.0	436.8	4	7.280	60	1920	128
														Guess						Total	19152	792

19944	Total TiwnAx links
5	Length per link (m)
3.3333333	Price $/m (=1.0$/ft)
332400	Total cost
398880	inc 20% contigency
434779	inc 9% OVH

TwinAX								1000ft	10000ft	Guess large	
Wire szie	Wire type	Length	raw	preemp	premp+8b1	width	height	price $/ft	price $/ft		
AWG30	CC-Al	6			6,2	2.159	1.4732	2	1		
AWG30	Cu	4.2672	1.56	<6.2	6.2	1.75	0.97	1.75		1.1	CC-Al
AWG28	Cu	6.096	3.11	3.11	6.22	2.39	1.32	1.6			
AWG34	Cu	4.2672	1.56	3.11	6.22	1.12	0.64	1.55		0.8	Cu
MWS wire											
AWG22	CC-Al wire								0.6		

6.1.8 UNM

CORE cost of Stave Flexes:

- one cable/half stave x 168 half staves (84 staves for L3/L4) x 5000 USD/cable = $840000 USD

6.1.4 OSU

Prototype work:

* ASIC: migrate 4-channel ASIC to 12 channels, design the 12-channel array receiver ASIC, testing of fabricated ASICs
* electrical design of opto-boards
* mechanical design of opto-boards
* build opto-board prototypes
* prototype opto-packs
* probe card design for testing opto-packs and ASICs
* design/fabrication of test system for long term reliability study of opto-boards
* design/fabrication of QA system for opto-boards
* long term reliability study of opto-boards
* 3 irradiations